1914
W12

WAGGONER

The Viability of Seeds as Affected by high Temperatures and Moisture Content

Botany

A. M.

1914

UNIV. OF
ILLINOIS
LIBRARY

THE UNIVERSITY
OF ILLINOIS
LIBRARY
1914
W12

Digitized by the Internet Archive
in 2013

http://archive.org/details/viabilityofseeds00wagg

THE VIABILITY OF SEEDS AS AFFECTED BY HIGH TEMPERATURES AND MOISTURE CONTENT

BY

HARRY DWIGHT WAGGONER

A. B. University of Illinois, 1909.

THESIS

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF ARTS

IN BOTANY

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1914

1914
W12

UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

May 28, 1914 190

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HARRY DWIGHT WAGGONER

ENTITLED THE VIABILITY OF SEEDS AS AFFECTED BY HIGH TEMPERATURES AND MOISTURE CONTENT

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF ARTS

Chas. F. Hottes
In Charge of Major Work

Wm. Trelease.
Head of Department

Recommendation concurred in:

Committee
on
Final Examination

284661

UIUC

CONTENTS.

	Page
Introduction	1
Method	3
Results of Experiments	5-7
Discussion	8
Conclusions	12
Bibliography	13

THE VIABILITY OF SEEDS AS AFFECTED BY HIGH TEMPERATURES AND MOISTURE CONTENT.

The question of the viability of seeds under various conditions has been one of great interest to investigators. Those who work from a purely scientific standpoint as well as those who are concerned on account of the commercial interests involved have attempted the solution of this problem. The former because of the light which a solution may shed upon the underlying principles of life; the latter because of the financial loss that seed deteriation entails.

The conditions under which the plant grew and the stage of maturity at the time of harvesting, play an important role in the life of the seed. It is also evident that care in curing and attention to the method of storing are of great importance from the standpoint of vitality. It is generally recognized now that marked variations in temperature more especially in the presence of high moisture content of the atmosphere or of the seeds during storage, are very injurious. Well dried seeds have been subjected to extremely low, as well as to very high temperatures, for long periods with but little, if any, injury. Moreover, the effects of some poisons on seeds vary with the amount of moisture in the seeds derived either from the atmosphere or from the surrounding soil.

On the whole it is clear that moisture content is one of the most important factors determining the life of the seed. In the literature concerning the effects of high temperatures on seeds many references are made to the importance of the consideration of moisture content. Little work, however, has been done to show the relation, if any, that exists between moisture content of seeds and their viability at high temperatures. The present work was undertaken and carried forward at the suggestion and under the guidance of Prof. C. F. Hottes, to whom the writer wishes to acknowledge his indebtedness.

The underlying aim in this series of experiments was to subject seeds containing varying but known quantities of moisture to high temperatures, and to determine the effect upon germination. It was necessary to consider several important points in carrying forward this work; first, to control the moisture content of the seeds, and to be able to determine with some degree of accuracy the amount present at the time of heating; second, to maintain the seeds during treatment at a uniform and constant temperature; and third, to provide an efficient method for germinating large numbers of seeds. The methods used to overcome these difficulties as well as others of minor importance will become clear from the discussion that follows.

METHOD.

The seeds used in these experiments were "Crystal Forcing," "Icicle" and "Black Spanish Winter" radishes, obtained from Dreer's Seed Co., Philadelphia. These varieties were selected for the purpose of comparing the relative resistence of types adapted to widely different conditions. The seeds were of good quality and throughout the experiments tested at from 88 to 91%. They were stored in glass stoppered bottles and random samples removed by means of a tin measure, when desired for experiments. No selection was made other than that those with ruptured seed coats were discarded.

The moisture content of the seeds was varied by placing the quantity used in each test in cheese cloth and soaking in water for a definite time. Thus by soaking for 15, 30 and 60 min. 21, 24 and 31% of water was taken up. After soaking the seeds were superficially dried with a towel and placed in the flasks for heating. The moisture content was determined by first obtaining the constant dry weight of a sample heated in a dessicator at 100° C and computing from it as a base, the percent of moisture in the seeds used in the tests. When it became necessary to reduce the water content below that of air dried seeds, the oven was used as indicated in table IV and the moisture determined as stated above.

The greatest difficulty was that of heating the seeds uniformly at the definite temperature desired. This was

finally overcome, in a great part at least, by using flat bottomed flasks large enough to allow the seed to lie in a single layer during the heating. The flasks were provided with corks through which glass tubes were passed that allowed communication with the outside. When seeds of low moisture content were subjected to high temperatures, solid corks were used to prevent a possible absorption of moisture. To facilitate the handling and to avoid error in heating, a wire cage was constructed in such a way as to hold the flasks furnished with the seeds two or three inches from the bottom of the bath. About thirty five liters of water were used in the bath - a quantity large enough to render it easy to control the temperature with a gas burner. A stirrer propelled by a water motor ensured a circulation of the water and thus a uniform temperature. When it became desirable to employ temperatures of 100° C and above, calcium chloride was added to the water in a small bath of five liters capacity. The degree of heat here was easily controlled as the boiling points could be raised or lowered by adding salt or water. A temperature up to 130° C could be obtained in this way.

Plaster of Paris blocks were used for germinating the seed. They were about five inches square and one and one-fourth inches thick. The smooth surface was marked off with a sharp edged instrument so that there were one hundred intersections suitable for retaining the seeds. This method saved much time in counting and was helpful in secur-

ing accuracy. After the blocks were filled with seeds and labelled, they were placed in fiber tubs and water was added to within one half inch of their upper surfaces. The tubs were then covered and kept in a dark room at a temperature of about 25° C. The fact that the fifty or more checks carried on during this series of experiments were practically constant, goes to show that the methods used for germination were entirely satisfactory.

One hundred seeds were used in each test so the tables that follow represent not only the number of seeds germinating but also the percent of germination. The discussion below will point out the most important facts to be observed.

TABLES OF DATA

Table I. Dreer's Crystal Forcing Radish.

	Temp. at which seed were heated for 30 min.											
Soaked	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	99°	Moisture
5½ hrs.	91	70	0	0								73%
2½	90	66	1	0								51
2	92	66	0	0								46
1½	93	71	1	0								39
1	-	75	24	0	0							31
30min.	-	83	74	26	0	0						21
15	-	82	81	66	19	10	0	0	0			14.1
5	-	91	84	80	68	47	39	13	3	0		12.2
2	-	91	93	91	83	74	71	56	28	0		10
Air Dry	-	-	-	-	91	94	88	88	74	25	0	5.3
Check	93	92	89	90	90	88	89	92	92	89	87	5.3

Table II. Black Spanish Winter Radish.

Soaked	Temp. at which seed were heated for 30 min. 50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	99°	Moisture
5½ hrs.	67	43	-									73%
2½	65	52	-									54
2	80	52	0									46
1½	83	56	7	-								43
1	-	62	46	0								35
30min.	-	73	67	0	0							27
15	-	76	81	37	21	1	0	0				21
5	-	85	86	78	49	37	33	26	0	0		14.2
2	-	88	88	86	67	55	50	38	7	0		11.1
Air Dry	-	-	-	90	87	90	82	77	66	38	0	4.1
Check	86	90	90	87	87	90	88	90	87	88	88	4.1

Check not heated.

Table III. Icicle Radish.

Soaked	Temp. at which seed were heated for 30 min. 50	55	60	65	70	75	80	85	90	95	99	Moisture
5½ hrs.	83	45										64%
2½	83	50										47
2	81	69	0									40
1½	81	72	14	0								36
1	-	74	25	0								31
30 min.	-	73	38	1	0							24
15	-	72	66	38	11	0	0					21
5	-	85	74	69	63	6	8	0	0			15.2
2	-	88	82	87	74	44	36	15	10	0		12
Air Dry	-	-	-	92	90	91	82	79	76	47	0	4.3
Check	86	88	87	89	90	90	87	89	90	89	88	4.3

Table IV. Icicle Radish. Continued.

Dessicated	Check	Temp. at which seed were heated for 30 min. 95°	100	105	110	115	120	123	125	Moisture
00 - Air Dry	89	47	0							4.3%
8 hrs at 53°	89	87	80	72	57	5	0	-	-	2.3%
48 hrs. at 53°	88	87	82	73	67	32	4	0	-	1.3%
72 hrs. at 53 8 hrs at 60°	90	-	-	85	86	62	32	0	0	.8%
72 hrs. at 53 72 at 60 2½ at 95°	84	-	-	84	68	64	25	14	0	.4%

The checks in table IV were dessicated as indicated but were not subsequently heated in bath.

Table V.

The delay in germination caused by subjecting seeds containing varying amounts of moisture to a temperature of 80° C for thirty minutes.

	Check	% of Water in seed when heated			
	4.3%	4.3%	12%	15%	21%
No. germinating the 1st day	149	30	2	0	0
" " " 2nd "	224	106	27	0	0
" " " 3rd "	71	176	85	37	0
" " " 4th "	15	86	121	54	0
" " " 5th "	9	13	50	29	0
" " " 6th "	3	1	18	8	0
" " " 7th "	0	0	0	1	0
Total germination	471	412	303	129	0

500 seed were used in each test.

Discussion.

The tables show that water content of seeds in the presence of high temperatures has a marked effect upon their viability. Air dry seeds withstood a temperature of 80° or 85° C with but little or no decrease in the percent of germination while seeds immersed in water two minutes and subsequently heated at 70° showed a considerable reduction; those soaked for one hour or even for a shorter time showed a marked reduction in the percent of germination at 55° or 60° C. As the moisture content of the seeds was increased, the temperature they were capable of bearing without injury, was considerably lowered. The seeds subjected to the same temperature were very differently affected depending on the amount of moisture present in the seed during heating. Those immersed for two minutes were not injured by a temperature of 65° C maintained for thirty minutes while those soaked for five, fifteen and thirty minutes respectively showed increased injury. After one hour's immersion in water all the seeds were killed when subjected to a temperature of 65° C for thirty minutes. It is clear that as the amount of water present in the seed is increased, a given high temperature becomes more injurious. These facts appeared constantly throughout the experiments. (Tables I, II, III, and IV.) Several investigators have called attention in a general way, to the important relations stated above. Farmer, in his work on albumen showed that in the absence of moisture the substance is reduced to relative molecular immobility, whereas

if water is present, coagulation occurs at successively lower temperatures depending on the amount of water present. Davenport, writing upon the effect of high temperatures upon organisms, concludes that "coagulation of protoplasm seems to be the cause of death." In working with seeds, Duvel arrives at the conclusion that respiration is in part the cause of death and that respiration is increased by an increase in the moisture content. He further calls attention to the importance of enzymes in seeds, but adds: "The evidence at hand goes to show that the life of the seed is not dependent on the preservation of the particular enzyme involved or on the zymogenic substance giving rise to the enzyme." The writer of this paper is concerned at present chiefly with the phenomenon itself and leaves for some future time the investigation of the underlying causes.

From a comparative study of Tables I, II and III it appears that there may be some difference in the resistance of the three varieties of seeds used, but the results throughout the experiments have not been constant enough to justify a positive statement. The "Dreer's Crystal Forcing" and "Icicle" radishes withstood 50° with high moisture content without injury, while the "Black Spanish Winter" at the same temperature and with approximately the same water content was injured. Again, at 95° C the air dry seeds of the "Black Spanish Winter" and "Icicle" radishes showed a much higher percentage of germination than did the "Dreer's Crystal Forcing." The difference in the resistance of air dry seeds to a temperature of 95° C may possibly be explained by the

fact that the moisture contents of "Black Spanish Winter" and "Icicle" were 4.1% and 4.3% respectively as compared to 5.3% in the "Dreer's Crystal Forcing." This difference in the water content may be sufficient at high temperatures to reduce the viability to the extent noted. The variations at 50° C and at other temperatures as shown in the tables can hardly be thus explained. On the whole it seems that the question of the comparative resistence of the varieties used had better be left until further evidence can be gathered.

One of the most noticeable phenomena throughout the series was the marked retardation due to the action of heat in the presence of moisture. Practically every test showed this to a greater or less extent. This will be clear from an examination of Table V the data of which was taken from an experiment carried on at 80° C as explained above. The same effects were noted at all the temperatures considered down to 55° C. Here, however, the delay in germination was much less than at the higher degrees. Thus, the check (Table V) which was not heated and contained 4.3% of moisture showed 75% germination in two days while similar seed containing 15% of moisture showed 0% in the same time. On the third and fourth days, the seeds that had been heated showed the greatest germination. The greater the quantity of water in the seeds at the time of treatment the greater was the delay in germination. Dixon in his work on the effect of high temperatures on seeds noted this increase in time needed for germination. Davenport in his chapter on the effect of

heat on protoplasm states that at a temperature slightly below the death point protoplasm becomes immobile but retains power to revive. My results obtained by subjecting seeds to high temperatures show that the greatest retardation occurs just below a temperature that proves fatal.

By removing water from air dry seeds by a moderate degree of heat, the resistence to high temperatures is increased. The moisture was driven off gradually as suggested by Dixon. Air dry seeds subjected to 100° C for thirty minutes were all killed while of those dessicated as above, indicated 14% germinated after being exposed to a temperature of 123° C (Table IV). These results agree in general with those of Dixon.

The rate at which air dry or dessicated seeds take up or give off water varies as indicated below. Air dry seeds took up water equivalent to 7% of their constant dry weight in two minutes while after soaking one hour they took up only 5% in the subsequent thirty minutes. In dessicating the air dry seeds for eight hours at 53° C they lost three percent of their dry weight but it required an additional forty hours at the same temperature to drive off additional water equivalent to one percent of their dry weight. In order to get rid of more moisture, the temperature had to be materially raised. (Tables III & IV). This shows clearly that air dry seeds rapidly take up the initial quantities of moisture and that as the amount of water in the seeds increases the rate at which water is taken up becomes less.

Moreover, in dessicating air dry seeds, water at first is rapidly driven off, and as the seed becomes more nearly dry the difficulty of getting rid of additional water increases. The several points discussed may now be summarized.

Conclusions

These conclusions apply to radish seeds heated for thirty minutes at temperatures ranging from 50° C to 125° C.

1. At a given temperature the viability of radish seeds varies inversely as the quantity of water present in the seeds.
2. With a constant water content the viability of radish seeds varies inversely as the temperature.
3. Subjecting seeds to high temperatures causes a retardation in germination, and at a given temperature this becomes more marked as the percent of water increases.
4. Seeds carefully dessicated can withstand temperatures up to 123°C and germinate.
5. The rapidity with which air dry seeds take up moisture when placed in water decreases as the seed become more nearly saturated.
6. The rate of loss of water during dessication decreases as the seeds become drier.
7. The results of this work do not justify a positive statement concerning the comparative resistence of the varieties of radish seeds to high temperatures.

BIBLIOGRAPHY.

1889 - Bailey, L. H. - On the influences of certain conditions upon the sprouting of seeds, Cornell Experiment Station Bulletin.

1908 - Davenport - Experimental Morphology.
Moisture on protoplasm, Chap. II.
Temperature on protoplasm, Chap. VIII.
Water on growth, Chap. XII.

1910 - Coulter, Barnes & Cowles - Textbook of Botany, vol. II.
Vitality of seeds, pp. 908-911.

1901 - Dixon, H. H.- Vitality of seeds.
Nature, vol. 64, p. 256.

1902 - Dixon - Resistance of seed to high temperatures.
Annals of Botany, vol. 16, p. 590.

1904 - Duvel, J. W. T., - The vitality and germination of seeds.
U. S. Dept. of Agriculture, Bulletin 58.

1900 - Farmer - Effect of dessication of albumen upon its coagulability.
Annals of Botany, vol. 14, p. 307.

1911 - Goodspeed, T. H. - The temperature coefficient of the duration of life in barley grains.
Botanical Gazette, vol. 51, p. 220.

1898 - Schimper - Plant Geography.
Chap. 2, pp. 35-53.

1899 - Thistleton - Dyer - Influence of the temperature of liquid hydrogen on the germinative powers of seeds.
Proc. Roy. Soc., vol. 65, p. 361.

UNIVERSITY OF ILLINOIS-URBANA
3 0112 086830400